10B.5 A REMARKABLE MESOSCALE SNOW BAND EVENT OVER SOUTHERN PA: A SNOW LOVER'S DREAM AND A FORECASTER'S NIGHTMARE

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1. INTRODUCTION

Forced mesoscale circulations occurring in the cold season are often associated with heavy snow rates, particularly when favorable moisture content and vertical motion fields are coincident with enhanced dendritic snow growth rates. Periods of moderate to heavy snowfall often result when convective or buoyant instability, conditional symmetric instability (CSI) or a combination of both organize to support a zone of banded precipitation.

Frontogenetical forcing in the presence of weak, moist symmetric instability poleward of an extratropical cyclone is recognized as the primary mechanism for the evolution and maintenance of mesoscale snowbands (Novak et al 2006; Nicosia and Grumm 1999). A second recognized synoptic-scale arrangement conducive for snowband formation is deformation to the north of a frontal surface or weak surface cyclogenesis (Banacos 2003). In this setup, confluent flow at 700 hPa tends to develop above a zone of low-level baroclinicity at the nose of an 850 hPa wind maximum, and within a zone of enhanced deformation.

Forecast strategies have been designed to identify synoptic regimes supportive of mesoscale banding as much as 48 hours in advance (Novak et al 2006). The forecast emphasis can be designed to evolve to the mesoscale within 24 hours of the event placing an emphasis on kinematic and mass fields supportive of frontogenesis and weak moist symmetric stability in the presence of available moisture. Recognition of these features can enhance a forecaster's situational awareness while reducing the surprise aspect that may accompany a heavy snow event.

The case presented here illustrates how a less than optimal, even innocuous synoptic setup nonetheless supported the development of a remarkable, mesoscale snowband that befuddled forecasters with up to 12" of snow in five hours over central Lancaster County, Pennsylvania during the late evening of February 3 and early morning hours of February 4, 2009 (Fig. 1). Observed snow rates exceeded 3" per hour during the height of the event which exhibited periods of cellular enhancement indicative of gravitational instability. Several reports of 8-12" of a low density snow occurred along an axis oriented north northwest to south southeast with major and minor dimensions of 30 km and 8 km, respectively (Fig. 2). A second zone of heavy snow developed to the northeast of the Lancaster County band delivering 6-10" of snow in a similar although much broader band from northwest of metro Philadelphia southeast into southern New Jersey. A third, less organized band delivered only light snow across Cumberland and Adams Counties, 20 km to the southwest of Lancaster.

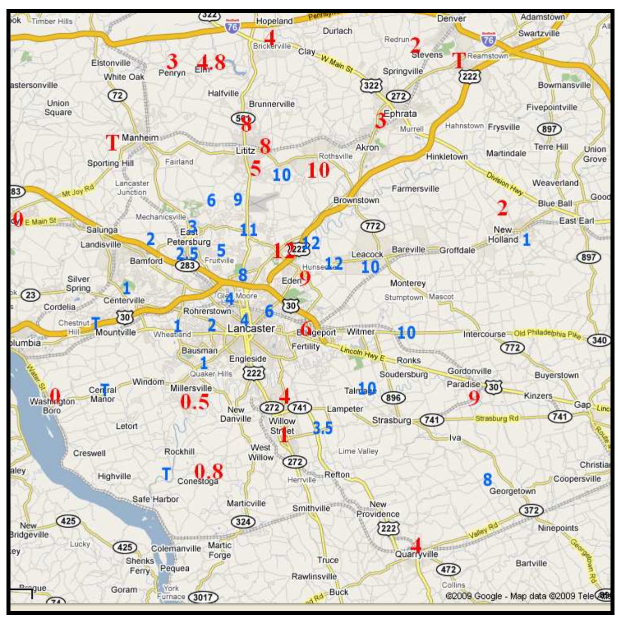

Fig.1 Observed snowfall totals (inches) over Lancaster County associated with the February 3-4, 2009 snowband from National Weather Service spotter observations (red) augmented with reports from Millersville University (blue).

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Fig. 2 The lead author's daughter assisting in the removal of 9" of a light, powdery snow the morning after the meoscale snowband event. Note the snow accumulation on the trees and on the deck railing in the upper right of the image.

2. SYNOPTIC SETTING

A highly amplified synoptic pattern characterized by a full latitude trough from James Bay to Florida and a 580 dm ridge centered over the desert southwest was present over N.A. during 3-4 February 2009. 500 hPa temperatures within the core of the upper-level cold air reached or dropped below -40 C over the eastern Great Lakes at 00 UTC 4 February 2009.

The Lancaster County snowband developed within a zone of weak low-level baroclinicity in the wake of a deepening north Atlantic cyclone to the northeast of a mid-level short wave moving southeast across KY (Fig. 3). The isotherm packing at 850 hPa revealed the presence of low-level cold advection off the continent in response to the aforementioned cyclogenesis. It should be noted that earlier guidance (i.e. preceding 48-72 h) placed the rapid deepening of the Nova Scotia low closer to the mid Atlantic coast leading some private forecasters to jump prematurely on the potential for a major coastal storm. They labeled this none event "Groundhogzilla" due to its proximity to the national day of prognostication.

A weak 850 hPa thermal ridge was also present at this time from CLT north northwest to CVG in advance of the KY short wave. This feature was identified by the Storm Prediction Center in a mesoscale discussion valid for 1544-1945 UTC 3 February 2009 as being associated with a low-level deformation axis and forced ascent. The anticipated forcing was expected to support the potential for banded precipitation with snow rates of 1-2 in/hour over eastern KY and southwestern OH.

A weak surface low and attendant cold front associated with this wave drifted off the NC coast by 12 UTC 4 February 2009 as a 1012 hPa cyclone and acted to reinforce the advection of cold, dry air from eastern Canada into the Northeast and northern mid Atlantic.

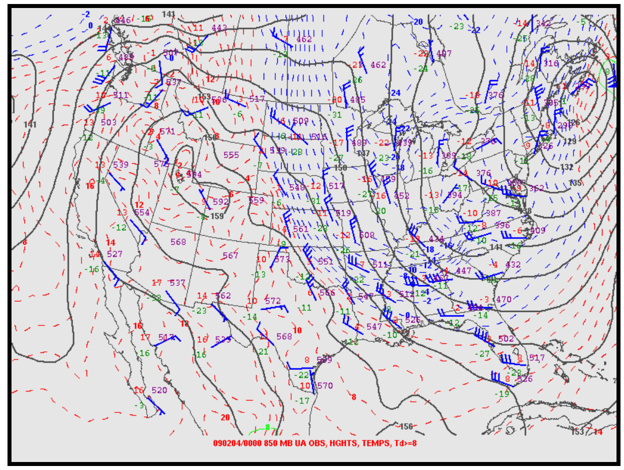

Fig. 3 850 hPa temperature and height fields at 00 UTC 4 February 2009 courtesy of the Storm Prediction Center.

A 700 hPa isobaric analysis from the 40 km NAM valid for 00 UTC 4 February 2009 revealed several impulses rotating cyclonically through a general, although complex positively-tilted trough upstream of southern PA (Fig. 4).

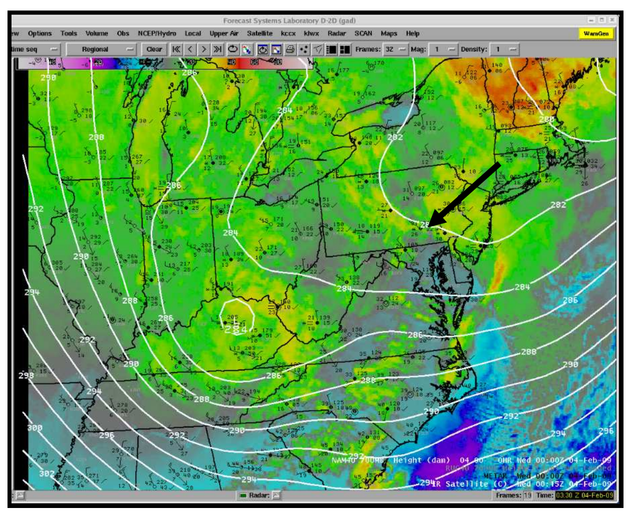

Fig. 4 NAM 40 km 700 hPa analysis (white lines) valid 0000 UTC, colorized IR satellite image valid 0015 UTC, and surface observations for 0000 UTC 4 February 2009. The broad cyclonic flow is advecting cold and exceptionally dry air from Quebec into the OH Valley and mid Atlantic. The black arrow identifies the Lancaster County band.

The NAM40 analysis reveals a surprising number of fine scale attributes associated with this event: 1) colder cloud top temperatures over eastern PA and southern NJ where 6-10” of snow was reported within a broad area of precipitation, 2) a northwest to southeast enhancement in the IR imagery from Lake Erie to the PA/MD border although not associated with heavy snow, 3) low-level thermal advection off the mid Atlantic resulting in cold air Cu downwind of the continent, and 4) mid-level (600 hPa) clouds within a warm advective regime streaming northeast ahead of a pronounced 700 wave/closed low near LOU. The Lancaster snowband is marked by the narrow zone of enhancement (black arrow, Fig. 4) nearly indistinguishable from the eastern PA/southern NJ snow field and the enhanced IR cloud field to the west where a dusting to an inch or two was reported over southern PA.

3. LOCAL OBSERVATIONS

Observations from the Lancaster County Airport (LNS) located within the northern portion of the band (Fig. 1, Route 501 south of Lititz) indicated the onset of moderate snow at 0145 UTC 4 February was accompanied by a drop in visibility to ½ mile. A period of moderate snow continued until 0321 UTC, and was marked by a light northwest wind of 6-8 mph and nearly constant temperature and dew point of 28 and 26 degrees F, respectively. The period of heavy snow marked by visibilities of ¼ mile or less and obscured skies occurred between 0236 – 0321 UTC. A second period of moderate to heavy snow moved across LNS between 0353-0442 UTC accompanied by a north northeast wind and a similar reduction in visibility.

The lead author measured 9” during the event from a position approximately 6 km south southeast of LNS (see 9” report east of Eden, Fig. 1); measured snowfall rates approached 3”/hour during the height of the event with a LEQ of 30:1, characteristics more commonly associated with lake effect snow or banded precipitation tied to rapidly deepening coastal cyclones than forced ascent within isolated mesoscale bands. The period of maximum dendritic growth produced large, beautifully formed crystals that fell and accumulated in the apparent absence of lightning.

The proximity sounding from Sterling, VA (IAD) taken at 00 UTC 4 February 2009 (Fig. 5) revealed an environment marked by an adiabatic layer from the surface to 830 hPa, some potential for low-level convective instability (requiring weak moistening) and a TOTL index of 46.6. The sounding depicted an unseasonably cold column evidenced by an observed thickness of 5147 m and a low tropopause height of 370 hPa.

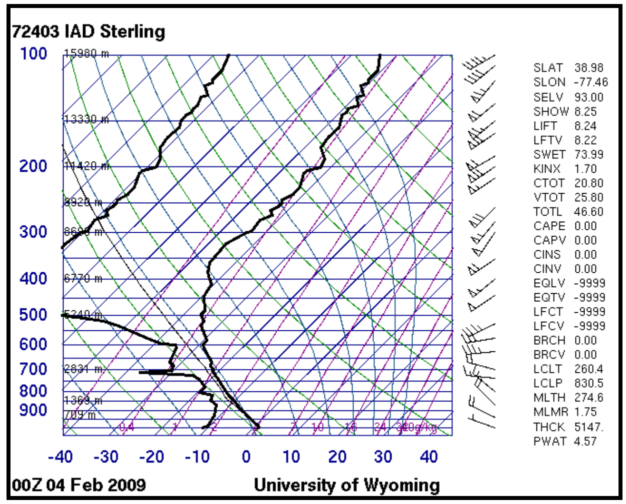

Fig.5 Observed sounding from Sterling, VA (IAD) from 00 UTC 4 February 2009 courtesy of the University of Wyoming.

4. MODELING EFFORTS

The fine-scale nature of the Lancaster County snowband and the absence of a direct association with surface cyclogenesis or marked low-level baroclinicity complicates the application of this event to conceptual models of forced mesoscale ascent described by Banacos (2003) or Berndt and Graves (2009). Conseuqently, a mesoscale modeling effort was undertaken to investigate the forcing responsible for the isolated heavy snowband as well as to assess the predictability of the event.

12 km NAM data provided the required vertical and lateral boundary conditions to initialize a 3-km version of the workstation Weather Research and Forecast (WRF) Model (Fig. 6). The model domain consisted of 45 vertical layers with model top at 50 hPa. The model was run explicitly given the size of the domain rather than utilize a convective parameterization scheme. Three high-resolution simulations were run to replicate the event with model output rendered through a series of GrADS scripts. A comparison of the output from the three simulations provided a subjective means for evaluating the degree of predictability afforded by the model and the confidence a forecaster might obtain from a high resolution operational forecast. The 30 km North American Regional Reanalysis (NARR) data was used to produce a comparative hindcast of the event.

Fig.6 Projection of 12 km NAM (lighter outline labeled "1") and 3 km WRF model (darker outline labeled "2") domains onto a U.S. map. The full field illustrated represents the domain of the 30 km NARR data.

5. DISCUSSION

The isolated character of the Lancaster County snowband is revealed by the base reflectivity image from the Fort DIX, NJ (KDIX) Doppler radar at 0319 UTC 4 February 2009 (Fig. 7). The northern portion of the band was past its most intense period at this time while that portion of the band positioned southeast of Lancaster continued to produce moderate to heavy snow. A much broader area of moderate to heavy snow centered southwest of Philadelphia is also easily discerned. The simulated reflectivity from the high resolution run initialized at 00 UTC on 4 February 2009 and valid at 03 UTC 4 February exhibits a substantial degree of detail not unlike the observed field, however, the Lancaster County snowband is displaced to the northeast (Fig. 7). Remarkably, the simulation reproduced the eastern PA and southern NJ event extremely well.

The 00 UTC 4 February WRF model simulations were compared with identical efforts initialized at 12 and 18 UTC 3 February 2009. A surprising degree of dissimilarity was evident in the results. Simulated reflectivity fields were not only displaced in time and space but represented poorly the intensity of the bands. While the "best" result is presented in Figure 7, we are reminded that the simulation was cold started just three hours earlier using a version of the WRF that is not available operationally to the forecaster. All simulations indicated the potential for locally moderate to heavy snowfall within the PHI CWA and possibly the CTP CWA but would a forecaster issue a special weather statement on the basis of this forecast given the rather benign synoptic-scale setup alluded to earlier?

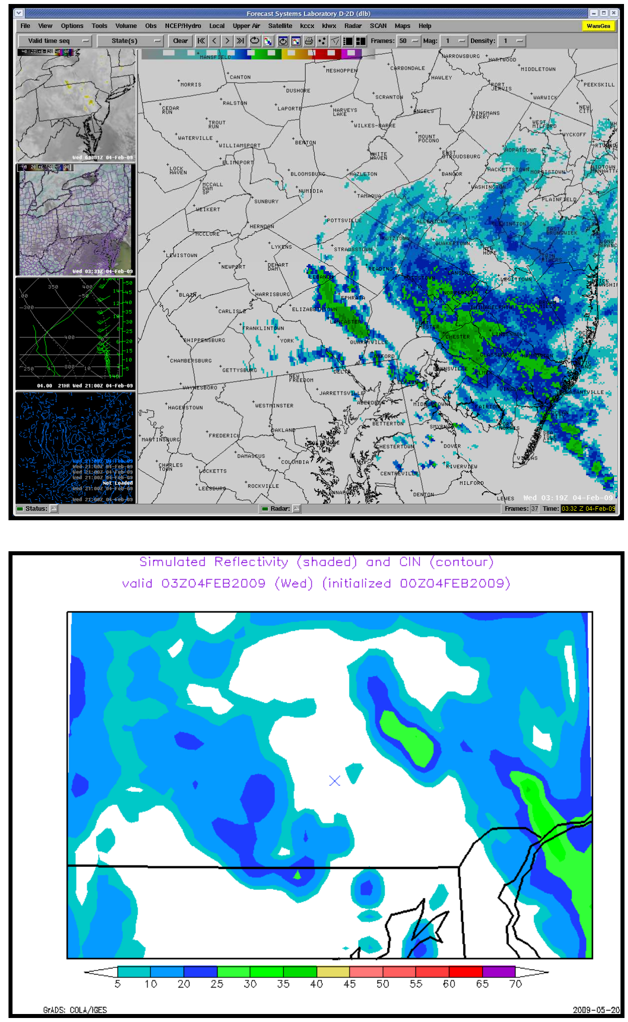

Fig.7 Top, base reflectivity image for 0319 UTC 4 February 2009 from KDIX. Bottom, simulated reflectivity from the high resolution WRF model initialized at 00 UTC 4 February 2009 and valid at 04 UTC. The "X" at the center of the image identifies Lancaster, PA. Note the broad area of light snow observed southwest of Lancaster was reproduced in this hindcast.

We can add to this discussion of predictability by examining plan view images constructed from the RUC40 and contoured every two hours between 02-08 UTC 4 February (Fig. 8). The fields depicted a nearly stationary zone of deformation over southeast PA during this period. A lobe of negative saturated equivalent potential vorticity (EPV) is coincident with the western margin of the 850-700 h deformation over southeast PA. This zone of negative EPV dissipates by 08 UTC 4 February as the region of 850-700 hPa deformation slides east of Lancaster County.

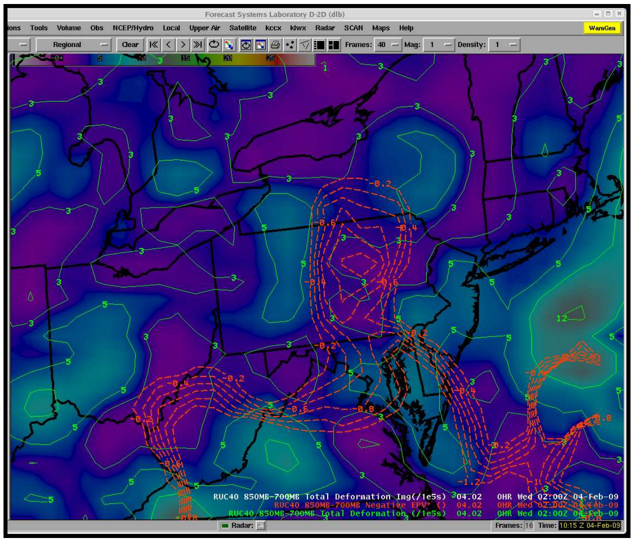

Fig.8 Total deformation valid 02 UTC 4 February 2009 shaded/contoured in green every 2 deformation units (/1e5s) and negative saturated negative EPV contoured in red every 0.2 PVU in the 850-700 hPa layer from the RUC40.

The extraordinary nature of the event is further revealed when one considers the maximum observed five-hour amounts approached approximately 45% of the 30-year climatology for seasonal snowfall across central Lancaster County. The limited scale and duration of the event emphasized the limits and uncertainties associated with higher resolution forecasts. The event also proved to be a success for the recently implemented NWS chat at the State College forecast office central PA.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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